Defense Technical Information Center Compilation Part Notice

ADP013918

TITLE: Evaluation of Uncertainty Budget for Antenna Calibration

DISTRIBUTION: Approved for public release, distribution unlimited

This paper is part of the following report:

TITLE: 2002 International Conference on Mathematical Methods in Electromagnetic Theory [MMET 02]. Volume 2

To order the complete compilation report, use: ADA413455

The component part is provided here to allow users access to individually authored sections of proceedings, annals, symposia, etc. However, the component should be considered within the context of the overall compilation report and not as a stand-alone technical report.

The following component part numbers comprise the compilation report:
ADP013889 thru ADP013989

EVALUATION OF UNCERTAINTY BUDGET FOR ANTENNA CALIBRATIONS

B. Türetken[1] S. E. San[2] M. Yazıcı[1] İ. Araz[1] A.İ. Yürekli[1] M. Hekim[3]

[1]TÜBİTAK-UEKAE, P.K.74, Gebze, 41470 Kocaeli TURKEY bahattin@uekae.tubitak.gov.tr
[2]TÜBİTAK-UME, P.K.54, Gebze, 41470 Kocaeli TURKEY
[3] GAZIOSMANPASA UNIVERSITY, Tokat MYO, Tokat TURKEY

ABSTRACT

Accurate field strength measurements for EMC conformance testing can be obtained by using antennas which have reliable antenna factors (AF). AF is a major component in calculating the uncertainty budget of an EMC test. So AF must be highly accurate and the equipment used for measurement must be traceable to a national standard. In a calibration process, it is important to obtain reliable data on two important characteristics : traceability and uncertainty. In this study, we report the evaluation of uncertainty budget in antenna calibrations. Parameters acting in this budget are explicitly presented. Apart from providing precise information about the characteristic uncertainty of device, such a budget permits the overall evaluation of the system so that one could think about possible innovations for reduction of measurement uncertainty [1].

INTRODUCTION

A measurement could be distinguished as a calibration under appropriate circumstances, if and only if, traceability and uncertainty information are included as a part of this measurement. In this study, we present the evaluation of uncertainty of antenna calibrations in the frame of conventional uncertainty estimation where partial derivatives of the fundamental formula constitute the basis of uncertainty budget [2,4]. Both A and B type factors, coming from random effects and known uncertainty values of devices respectively, are concerned in the evaluation process.

THEORY

Those equations that can be concerned as the starting point are listed below:

$$AF_1 = 10\log f_M - 24.46 + 1/2[\,E_{D\max} + A_1 + A_2 - A_3] \tag{1}$$

$$AF_2 = 10\log f_M - 24.46 + 1/2[\,E_{D\max} + A_1 + A_3 - A_2] \tag{2}$$

$$AF_3 = 10\log f_M - 24.46 + 1/2[\,E_{D\max} + A_2 + A_3 - A_1] \tag{3}$$

where; $E_D^{\max}$ is the maximum received field at separation distance R from the transmitting antenna, $AF_{1,2,3}$ are the antenna factors of antennas 1,2 and 3 in dB(1/m), $A_{1,2,3}$ are the measured site attenuation results in dB. f is the frequency in MHz [3].

In the scope of the uncertainty evaluation, partial derivatives of the starting equation with respect to the included parameters are constituted in the following manner:

$$D_1 = \frac{\partial}{\partial f_M}(AF_1) + \frac{\partial}{\partial E_{D\max}}(AF_1) + \frac{\partial}{\partial A_1}(AF_1) + \frac{\partial}{\partial A_2}(AF_1) + \frac{\partial}{\partial A_3}(AF_1) \tag{4}$$

Absolute values of these partial derivatives yield, $10/f_M$, 1/2, 1/2, 1/2, 1/2 respectively, and the uncertainty of the system could be established on this basis as follows:

$$U = \sqrt{(10/f_M)^2 \Delta f_M{}^2 + (1/2)^2\,\Delta E_{D\max}{}^2 + (1/2)^2 \Delta A_1{}^2 + (1/2)^2 \Delta A_2{}^2 + (1/2)^2 \Delta A_3{}^2} \tag{5}$$

where U is the total uncertainty and Δ terms represent the individual uncertainty values of the corresponding quantities. In the numerical step, evaluation all terms inside the square root are expressed either by certificate values of the devices in use (i.e. B type), or statistical evaluation of the data of the measurement (i.e. A type). In the case of A type uncertainty, repeatability of

the measurement plays an important role and reliability of this factor increases as the number of measurements increase. It is a convenient preference to multiply the obtained uncertainty value U by 2 so that an extended uncertainty is concerned and this situation is generally denoted as uncertainty at k=2.

EXPERIMENTAL RESULTS

We have applied ANSI C63.5-1998 Standard Site Method (SSM) in an Open Area Test Site (OATS) [3]. UEKAE has a large flat outdoor ground plane which has been shown to act as a near-perfect mirror at VHF frequencies. The SSM, based solely on horizontally polarized measurements, provides antenna factor measurements from 30 MHz to 1000 MHz. The measurement distances are 3m and 10 m, transmiting antenna heights are 1m and 2m, and receiving antenna search heights are from 1m to 4m. The methods are used for horizontal polarization on a standard antenna calibration site. The SSM requires three site attenuation measurements under identical geometries using three identical antennas taken in pairs, as shown Figure 1.

$$AF_1 + AF_2 = A_1 + 20\log(f_{MHz}) - 48.92 + E_{Dmax} \quad (6)$$
$$AF_1 + AF_3 = A_2 + 20\log(f_{MHz}) - 48.92 + E_{Dmax} \quad (7)$$
$$AF_2 + AF_3 = A_3 + 20\log(f_{MHz}) - 48.92 + E_{Dmax} \quad (8)$$

There are two measurement procedures that may be used to determine site attenuation: *discrete frequency method* and *swept frequency method*. We have used *swept frequency method* controlling the test equipment by using a computer interface (Figure 1).

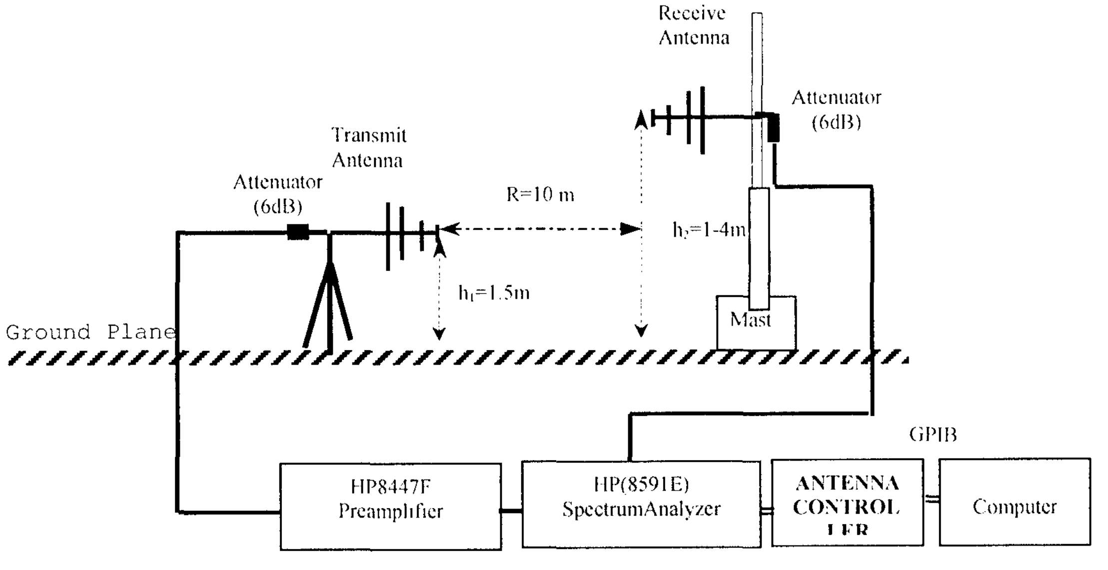

Figure 1. Test Setup for Determining the Antenna Factor

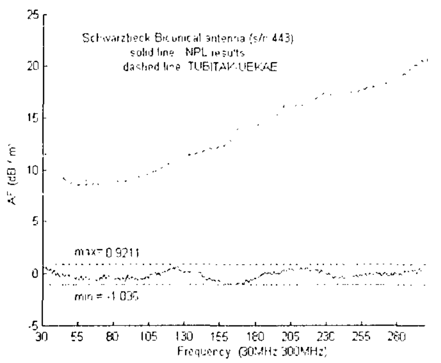

Figure 2. Antenna Factors of Schwarzbeck Biconical Antenna (s/n: 443)

We have obtained the antenna factors of Schwarzbeck biconical antenna (s/n:443) with a very good agreement between the NPL measurement results (Figure 2).

Table 1. Estimated Uncertainities (30MHz-1000MHz)

Description of uncertainty	**Coverage factor**	**Biconic Antenna**		**Log-Per Antenna**	
		3m	**10m**	**3m**	**10m**
Cable Attenuation	Normal k=2	± 0.3	±0.3	±0.3	±0.3
Receiver Specifications	Rectangular $k=\sqrt{3}$	± 0.2	±0.2	±0.2	±0.2
Preamplifier	Rectangular $k=\sqrt{3}$	± 0.4	±0.4	±0.4	±0.4
Attenuator	Rectangular $k=\sqrt{3}$	± 0.3	±0.3	±0.3	±0.3
Height Measurement	Rectangular $k=\sqrt{3}$	± 0.6	± 0.4	± 0.6	± 0.4
Distance Measurement	Rectangular $k=\sqrt{3}$	± 0.6	± 0.4	± 0.6	± 0.4
Site imperfections	Rectangular $k=\sqrt{3}$	± 0.04	± 0.04	± 0.05	± 0.05
Maximum measured	Standard deviation	± 0.6	± 0.6	± 0.8	± 0.8
Combined standard	**Normal k=2**	**0.84**	**0.765**	**1**	**0.93**
Expanded uncertainty	**Normal k=2**	**1.69**	**1.53**	**2**	**1.86**

By using equation (5) combined standard uncertainty can be calculated as follow:

$$U=\sqrt{\frac{0.3^2}{4}+\frac{0.2^2+0.4^2+0.3^2+0.6^2+0.6^2+0.04^2}{3}+0.6^2}=0.84$$

CONCLUSION AND DISCUSSION

The antennas were identical biconic and log periodic antennas covering the frequency range of 30 MHz to 1GHz. The data were measured at 800 frequency points using spectrum analyzer, low loss cables, and a positioning with 1cm . The test was performed at 3 and 10-meter separation, 1.5-meter transmit height, and 1-to 4-meter scan height per ANSI C.63.5 on an open area test site (OATS).The standard deviation of 12 (biconic and log periodic) antenna factors and their maximum deviations from the average are calculated. Another systematic error contribution is the max-hold height step. For continuous height scanning, this is a function of sweep time versus tower speed. The final and most troubling contribution is site imperfections. For this purpose, scattering objects nearby are cleaned, measurement site is wiped with sandpaper and painted. Directivity of antennas are positioning of the cables are adjusted so as to minimize reflections. Recording of the measurement results are perfomed automatically in order to overcome uncertainity due to personnel failure in reading. The estimated uncertainties in the measured antenna factors are listed Table 1.

REFERENCES

[1] M.J. Alexander, M.J. Salter, D.G. Gentle, K.P. Holland "Advances in measurement methods and reduction of measurement uncertainities associated with antenna calibration" IEE Proc. –Sci Meas. Technol., Vol.141, No.4, July 1994

[2] International Organisation for Standardisation 1993-Guide to the expression of uncertainty in measurement,

[3]ANSI C63.5-1998 American National Standart for Electromagnetic Compatibility-Radiated Emission Measurements in Electromagnetic Interference (EMI) Control-Calibration of Antennas (9kHz-40 GHz)

[4] M. D. Foegelle, "A statistical Approach to Measurement Uncertainty" Antenna Catalog Essential Equipment for EMC Testing-EMCO 1998.